

FINAL REPORT for NOAA NA10OAR4310217

California Nevada Activities in Support of a National Climate Assessment

Award Period: 09/01/2010 - 08/31/2013

1. Who are your Team Members?

Daniel Cayan, Michael Dettinger, Kelly Redmond, Anne Steinemann, Tim Brown, Alexander Gershunov, Randall Hanson, Sam Iacobellis, Nina Oakley, David Pierce, Mary Tyree, Tamara Wall, Anthony Westerling, and Monique Myers.

2. What are your areas of focus or partnerships?

- Great Basin Climate Forum Series. In collaboration with the Great Basin Landscape Conservation Cooperative, we have held three of these meetings in Reno, NV and a northern meeting in Klamath Falls, OR (in collaboration with the Pacific Northwest Climate Impacts Research Consortium (CIRC RISA). These meetings have focused on providing natural resource managers with applied current climate and weather information to specific resource issues relevant to the region (i.e., drought, wildfire, invasive weeds). Future forums will be held during the spring in Reno and the fall forum will float around the Great Basin. The Fall 2013 meeting will be held in Bishop, CA on October 16th. These meetings have provided an outstanding mechanism to 1) better understand the climate-related research needs of managers and 2) develop relationships and networks across the Great Basin to better enable the utilization of science in management decisions.
- Great Basin Water Forum. Kelly Redmond and Tamara Wall have attended the Great Basin Water Forum meetings for the last three years, chaired by Steve Bradhurst. Kelly Redmond presented at the 2012 meeting held in Ely, Nevada and will also present this fall at the Bishop, CA meeting. The Ely meeting also featured a day-long field trip to the source area for the proposed water pipeline to Las Vegas. In conjunction with the Great Basin Water Forum, we have also worked with the Central Nevada Water Authority to identify research needs and gaps for the region related to water resources.
- Washoe County Regional Resiliency Plan. Kelly Redmond, Tim Brown, and Tamara Wall began working with the Washoe County emergency manager's office, as well as representatives from other county offices and the cities of Sparks and Reno, to develop a regional resiliency plan for Washoe County. They would like to better incorporate climate considerations in this process. Using the city of Flagstaff, AZ's Resiliency and Preparedness 2012 Study as a starting point, the group hopes to have a rough draft completed this fall and use it to support a proposal to the Rockefeller's 100 Resilient Cities initiative and the County's 2015 FEMA multi-hazards report.
- Modeling wildfire for climate change assessment in California and the Rockies, in partnership with USDA Agriculture and Food Research Initiative (AFRI). This effort incorporates dynamic vegetation modeling into projections for wildfire and wildfire

emissions under climate change scenarios in CA and the Rockies. A primary focus is on stakeholder outreach in the Tahoe Basin, assessment of stakeholder needs and capacity to assimilate and use research outputs, and methods to effectively communicate (via language and visualization) research results to sophisticated stakeholder communities. The results of the Tahoe-centered stakeholder exercises are applied to generating online materials for use in forest management and forest community planning activities around the West.

- National Integrated Drought Information System (NIDIS). We have been leading the California Pilot, which includes the Southern California, Russian River, Central Valley, and Klamath Pilot Activities, to develop drought information products to help decision-makers and stakeholders reduce drought impacts. In Southern California, we have engaged and partnered with over 50 stakeholder groups, representing a range of agencies, organizations, industries, and tribes, including the California Department of Water Resources, San Diego County Water Authority, Metropolitan Water District, City of San Diego, U.C. Irvine, Western Municipal Water District, Pala Band of Mission Indians, U.S. Geological Survey, San Diego Gas and Electric, University of California Riverside, Sweetwater Authority, Jet Propulsion Laboratory, RAND Corporation, National Drought Mitigation Center, California Nevada River Forecast Center, San Bernardino Valley Municipal Water District, Orange County Water District, California Avocado Commission, Coachella Valley Water District, Water Replenishment District of Southern California, Camp Pendleton Marine Corps Base, Olivenhain Municipal Water District, National Interagency Fire Center, Los Angeles Department of Water and Power, National Weather Service, United Water Conservation District, Nettleton Strategies, U.S. Bureau of Reclamation, and Native American Environmental Protection Coalition. The Klamath Pilot Activity is developing methods to better characterize drought status in the Klamath Basin. This activity is teaming with a NOAA Sector Applications Research Program (SARP) project led by Mark Deutschman of Houston Engineering in Minneapolis that features extensive stakeholder engagement in the Upper Klamath Basin to learn what is desired. Through this activity their Klamath Decision Support System may migrate to WRCC.
- Climate Change Education Partnership (CCEP-II): We are active in the Climate Education Partners (<http://www.sandiego.edu/climate/>) who received a National Science Foundation grant to develop a climate change education plan for the San Diego region. The Partnership is working with local civic, business, government, and education leaders to study local perspectives regarding climate change and its impacts on the San Diego region. The goal of the project is to understand how best to communicate the causes of climate change, and its regional impacts, and how to adapt to or prevent those impacts on our region. The Partnership is one of fifteen groups nationwide to receive National Science Foundation funding to develop climate change education strategies, presenting us with a unique opportunity for the region. The outcome of this project is a strategic communications plan for the San Diego region. The project uses regional climate science results to educate the community leaders and the public about climate change.

3. Please provide a list of 1 - 5 research findings

- Forest wildfire regimes in the northern and central US Rockies are close to a tipping point; only a small additional increment of warming is required to lead to widespread transformation via fire and other disturbances of vegetation and fire regime characteristics. Wildfire in California is less sensitive to warming, but will also increase in mountain forests. Emissions from fire in California will increase, particularly in the Sierra Nevada, and future emissions from fire are not sensitive to development and population growth scenarios, because most vulnerable biomass is concentrated on public lands.
- Fuel treatments in Southern California forests should be planned for summer fuel-driven fires, not fall Santa Ana wind-driven fires, and a summer climatology window that excludes Santa Ana conditions (e.g., May 15 – Sept 15) should be used to model fire behavior and test treatment effectiveness. Southern California fuels are projected to experience significant increases in flame length, rate of spread, crown fire and other important fire behavior metrics. Current fuel treatments will likely not meet effectiveness objectives by the mid-21st century.
- A survey of California coastal professionals identifies regionally specific climate projections (for the next 2-3 decades) as the most useful information about the physical environment. Aspects of these projections that are vital to their needs include sea level rise information for their specific region or community; predictions of changes in flooding or erosion; shoreline change data currently and under different sea level rise scenarios; tidal change information; and information about change in future water quality and freshwater availability. Sea level in California (south of Cape Mendocino) could rise by 1 m by 2100, about the same as global sea-level rise. Sea-level rise will magnify the adverse impact of storm surges and high waves on the coast.
- Across the western U.S., drought damages over the past 1-2 decades have averaged an estimated \$1.1 billion per year, ranging from millions to multiple billions of dollars. Better early warning information could help reduce drought impacts, with an average reduction of 33%, according to state drought managers.
- The Great Basin Forum, now an ongoing activity, investigates the usability and social perspectives of climate information in the Great Basin. The results from this activity have begun to affect the development and implementation of experimental (CNAP) and operational (WRCC) climate products and services in the region. A particular issue is that 20-60 percent of annual precipitation along the West Coast, including the Great Basin, is associated with closed upper low pressure systems. The Pacific Ocean west of the U.S. is a preferred Northern Hemisphere location for such systems. The evolution of these often-slow-moving systems poses difficult forecasting challenges in comparison with other sources of West Coast precipitation. Their strongest associations with global climate patterns are positive correlations with El Nino, with positive Pacific Decadal Oscillation, and with the Pacific North America pattern. Little evidence exists of temporal trends in frequency or other characteristics.

4. Please provide a summary of 1 – 5 narrative ACCOMPLISHMENTS – These should be similar to what you submit to the RISA Annual Report as “Highlights” and describe outcomes of individual projects or the combination of multiple projects over the course of your award.

Climate Change, Vulnerability, and Adaptation Assessments

Tyree, Gershunov, Dettinger, and Cayan have contributed to assessments of climate change in California and in the Southwestern U.S., focusing on physical aspects of regional climate change and sea level rise. Since 2006 the scientific community in California, in cooperation with resource managers, has been conducting periodic statewide studies about the potential impacts of climate change on natural and managed systems. Cayan helped organize and is contributing to an ongoing Vulnerability and Adaptation Assessment, California-wide as well as in the San Francisco Bay region. He also served as one of the editors of a Special Issue of Climatic Change which describe results from the California Climate Change Scenarios Assessment, concluded in 2009. As with the 2006 studies that influenced the passage of California’s landmark Global Warming Solutions Act (AB32), these papers have informed policy formulation at the state level, helping bring climate adaptation as a complementary measure to mitigation. Coastal sea level variability and change is connected to water resources and ecosystems in California in several ways, one of which is because much of the state’s water supply is extracted from the inland reaches of the San Francisco Bay/Delta estuary. Cayan also participated in the NRC Panel investigating sea level rise along the West Coast of the U.S. and was a member of the National Climate Assessment sea level rise team.

Southwest Climate Change Assessment and California Climate Vulnerability Assessment

We describe possible climate changes in temperature, precipitation, and other measures projected to evolve during the twenty-first century for California and the Southwest United States, as compared to recent historical climate. The projections derive from the outcomes of several global climate models, and associated “downscaled” regional climate simulations, using two emissions scenarios (“A2” or “high emissions,” and “B1” or “low emissions”). Projected changes in mean climate and extreme events in the Southwest are described in Chapters 6 and 7 of the Southwest Climate Change Assessment. Our climate change assessments find that surface temperatures in California and the Southwest will rise substantially (by at least 3°F, but probably more, over recent historical averages) over the twenty-first century from 2001–2100; the amount of temperature rise will be higher in summer and fall than winter and spring. There will be a reduction of mountain snowpack during February through May from 2001 through 2100, mostly because of the effects of warmer temperature. On the whole, the projections indicate that precipitation will be lower in the southern portion of the Southwest region and little change or increasing precipitation in the northern portion, but there is considerable variability across models and simulations. Climate variations of temperature and precipitation over short periods (year-to-year and decade-to-decade) will continue to be a prominent feature of the Southwest climate. Substantial parts of the Southwest region will experience reductions in runoff and streamflow from the mid- to end of twenty-first century. We provide an evaluation of physical elements of climate change and sea level rise that are contained in the California Climate Change Vulnerability and Adaptation Assessment. The analyses use six global climate models, each run under the Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios

B1 and A2 scenarios. From the global climate models and associated downscaled output, these scenarios contain a range of warming, continued interannual and decadal variation of precipitation with incremental changes by the middle and end of the twenty-first century, substantial loss of mountain snow pack, and a range of sea level rise along the California coast. This investigation is summarized in a Report to the California Energy Commission.

Several CNAP team members contributed to the publication “Assessment of Climate Change in the Southwest United States” (hereafter, *Climate Change in the Southwest*, or CCSW), published by Island Press in 2013. Lead authors for this publication included: Kelly Redmond, Dan Cayan and Mike Dettinger on Chapter 1 (Summary for Decision Makers); Kelly Redmond on Chapter 4 (Present Weather and Average Climate Conditions); Mike Dettinger on Chapter 5 (Present Weather and Climate: Evolving Conditions); Dan Cayan, Mary Tyree, and Sasha Gershunov on Chapter 6 (Future Climate: Projected Average); Dan Cayan, Sasha Gershunov, Mike Dettinger, and Kristen Guirguis on Chapter 7 (Future Climate: Projected Extremes); Tim Brown and Sasha Gershunov on Chapter 15 (Human Health); and Francisco Munoz-Arriola on Chapter 16 (Climate Change and U.S.-Mexico Border Communities). In addition Kelly Redmond contributed to two reports (lead author Ken Kunkel) submitted in support of the National Climate Assessment, for the Southwest and the Northwest U.S., respectively.

Great Basin Climate and Social Perspectives

The Great Basin region is one of the most climatically variable areas in the United States. Covering most of Nevada and portions of California, Oregon, and Idaho, this region is known for its aridity, temperature swings, and elevation changes. Future climate forecasts suggest that this area will be affected by changing climate conditions, becoming warmer with changes to the water cycle. Understanding the social perspectives regarding climate information in the Great Basin is key to increasing the saliency and usability of climate information in the region. Identifying the usability and social perspectives of climate information in the Great Basin is necessary to assess the adequacy of current mechanisms for distributing climate information. Given the current knowledge gap, the ability of institutions responsible for providing climate services and products is reduced. This research is addressing this knowledge gap by assessing current social perspectives on the adequacy of climate information and tools available for the Great Basin region. The results from this activity have begun to affect the development and implementation of experimental (CNAP) and operational (WRCC) climate products and services in the region.

Assessment of CNAP Stakeholders and Scientists

Modeled on a similar study done by the Alaska Center of Climate Assessment and Policy (ACCAP), this study examined the role of CNAP scientists in producing climate-related knowledge for stakeholders, the relationships between CNAP scientists and stakeholders, and how both viewed the value of their relationships and the knowledge produced. The project will be used to help build an evaluation component for CNAP, and has recently received approval from the University of Nevada’s Institutional Review Board to continue enrolling new participants. A peer-reviewed publication is in development.

California Climate Extremes Workshop

In collaboration with the presenters at the California Climate Extremes workshop (SIO, La Jolla, 13 December 2011), Dave Pierce of CNAP wrote and produced the workshop report. The report is designed to provide useful information on evolving weather and climate extremes for stakeholders and decision-makers in industry, government, and local community groups. Topics covered include heat waves, water supply, sea level and coastal flooding, reservoir management, agricultural and ecological impacts of extreme events, wildfires, and the human health and economic implications of extreme events. The report was distributed to the workshop participants, as well as to attendees of the Association of Pacific Rim Universities Coastal Cities and Sea Level Rise workshop (SIO, La Jolla, 5-7 Sept 2012), and the California Energy Commission's Integrated Energy Policy Report (IEPR) workshop on climate forecasts and change for energy applications (California Energy Commission, Sacramento, 30 April 2012).

National Integrated Drought Information System (NIDIS): California Pilot and Southern California Pilot Activity

Drought is one of the most costly natural disasters. For the state of California, with its climatic and human-developed complexity and diversity of droughts, traditional drought products, such as the U.S. Drought Monitor, are not well suited to describe, assess, and predict drought conditions. The California NIDIS Pilot is developing and demonstrating a variety of early warning and drought risk reduction strategies, in partnership with more than 100 stakeholders from agencies, industries, organizations, tribes, and members of the public. The Southern California NIDIS Pilot Activity is investigating drought issues in a major metropolitan area where water supplies are primarily imported, the water system is heavily engineered, and drought often depends on more than hydrology and typical indicators. Products will include stakeholder-based applications of drought early warning information, regionally relevant indicators for assessing and forecasting drought, a statewide drought resources portal, and new resources and approaches that capture the complexities of California droughts, and that can be transferred to other areas.

Evaluating Our Capacity: A discussion of Capability for Ongoing Climate Assessment in the Colorado River Basin

Done in collaboration with the Climate Assessment for the Southwest (CLIMAS), this workshop brought together a diverse group of professionals working in the Colorado River Basin June 6-8th, 2011 in Boulder, CO. Participants tried to answer two main questions during the workshop: What is our capacity for conducting ongoing assessments of climate vulnerabilities, impacts, and adaptive capacity? What is our capacity to evaluate the efficacy of our efforts to adapt to regional climate changes and their impacts? The workshop summary provides a roadmap for considering how to move forward with climate change assessment and adaptation efforts in the Colorado River Basin (Wall, Garfin, and Galayada 2012).

5. Results from surveys of stakeholders; whether stakeholders had knowledge of and/or used national assessments material (such as prior NCA reports, web site information, etc.). Please report findings (which will be conveyed to NCA people).

The CNAP team was one of four lead organizations that conducted the California Coastal Climate Adaptation Needs Assessment survey. Fifteen partner organizations collaborated in this survey of nearly 600 California coastal professionals. Respondents were asked about their climate change knowledge, concerns and actions; climate change information they use and how

they access it; current management challenges and their needs to support climate adaptation planning and implementation. The most frequently used source of information was the internet, and the second most frequently used source was colleagues at work, with approximately 75% of respondents consulting them "all the time" or "frequently." State and federal agencies were third and fourth most used, respectively, with over 60% of respondents consulting them "all the time" or "frequently." Over 50% of respondents indicated they regularly consult sea level rise projections and climate and weather information for their daily work. The most useful climate information source to help coastal professionals assess the risk to local coastal resources was regionally specific climate projections (for the next 2-3 decades). As the most useful information about the physical environment, government and NGO staff identified sea level rise information for their specific region or community; predictions of changes in flooding or erosion; shoreline change data currently and under different sea level rise scenarios; tidal change information; and information about change in future water quality and freshwater availability.

Each of the Great Basin Climate Forums has pre and post forum survey data gathered by Tamara Wall to identify natural resource manager's concerns, the effectiveness of the forum in providing relevant and useful climate information, and suggestions for improvements. A brief summary of this data indicates that just over 95% of the forum participant's rank current or potential climate conditions as medium to high in their overall ranking of issues to be concerned about as managers. In addition, 69% of the participants responded that they use climate or weather related information in management decisions a moderate amount to everyday each month. These responses indicate that there will be a need for continued enhancements in the delivery and quality of climate related research, observation, and monitoring data in the Great Basin region.

6. List of completed publications. (Internet links and personal-use pdf files available on the CNAP website http://meteora.ucsd.edu/cap/cap_references.html)

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Dettinger, M.D., and B.L. Ingram, 2013: The coming megafloods. *Scientific American*, 308(1), 64-71.

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